- 1 -

ZOOM LENS

BACKGROUND OF THE INVENTION

5

1. Field of the Invention

The invention relates to a zoom lens comprising in a
direction of light propagation a front lens group hav-
10 ing positive refractive power, a variator lens group
having negative refractive power, a compensator lens
group having positive refractive power, a base lens
group having positive refractive power.

15 Numerous zoom lenses are already known from the prior
art. The zoom lenses must fulfil specific optical
and/or mechanical properties, depending on requirement.

2. Description of the Related Art

20

Zoom objectives for photography typically have a zoom
factor of 2 to 4. The exit pupil vision is not telecen-
trically configured here. The installed length is to be
kept as short as possible with these zoom lenses.

25

Furthermore, zoom lenses for video recordings, for ex-
ample camcorders, are known from the general prior art.
The CCD detectors used in this case have an image di-
ameter of at most 11 mm. The zoom factor is specified
30 here mostly as 10, the focal range reaching from 3 mm
to 50 mm in known makes.

The zoom factor for such lenses is approximately 20 to
30 in the case of zoom lenses for television re-
35 cordings. The CCD detectors used in this case have an
image diameter of typically 11 mm. Focusing is per-
formed here by the front group, as a rule. These lenses
must have a long back focus in order to be able to in-

- 2 -

stall a color-splitting prism between a last lens and a
detector.

Afocal zoom lenses are frequently used as component
5   parts in instrumental optics. The diaphragm position
can be varied during the zooming operation in the case
of such systems.

None of the zoom lenses enumerated corresponds per se
10 to the desired characteristics of a zoom lens for mili-
tary reconnaissance. It is also impossible to create
other characteristics for the said zoom lenses by a few
and simple conversions by means of known optical com-
puting programs. Moreover, the multiplicity of afocal
15 zoom lenses have a smaller diameter to achieve a con-
stant aperture number over a focal range of up to ap-
proximately 280 mm in combination with a lens of suit-
able focal length.

20   **SUMMARY OF THE INVENTION**

Consequently, it is an object of the invention to cre-
ate a zoom lens that fulfils the requirements with ref-
erence to optical properties and focusing characteris-
25 tics, the aim being for the installation space, of
which only a limited amount is available, to be kept as
small as possible, and for the zoom lens to be capable
of functioning in a temperature range from -35°C to
+75°C.

30

According to the invention, this object is achieved by
virtue of the fact that the base lens group comprising
a first base lens group and a second base lens group,
wherein the front lens group, the variator lens group,
35 the compensator lens group and the first base lens
group are arranged along a common straight first opti-
cal axis, wherein the second base lens group is ar-
ranged along a second optical axis inclined with re-

- 3 -

spect to the first optical axis at a first angle α dif-
ferent from 0° and 180°, and wherein a beam deflector
is arranged between the first base lens group and the
second base lens group.

5

The zoom lens comprises a front lens group, a variator
lens group, a compensator lens group and a base lens
group, the base lens group being split into two groups
with a positive refractive power in each case. Split-
10 ting the base lens into two produces a relatively large
air space between the first base lens group and the
second base lens group. The second base lens group of
the base lens group is arranged at a specific angle α
to the first base lens group of the base lens group, it
15 being advantageously possible thereby for an at least
approximately L-shaped arrangement of the zoom lens to
be produced. A plane mirror for beam deflection is ad-
vantageously located in the air space between the first
base lens group and the second base lens group.

20

Such an arrangement can be used to implement the spe-
cial characteristics for a zoom lens for military re-
connaissance, the result being a zoom lens of high im-
aging quality, compact installation space because of
25 the angle α, large zoom factor and large spectral
range.

It can be provided advantageously that the first base
lens group and the second base lens group are arranged
30 at a distance along the first and second optical axis,
which distance is at least 15% of the overall length of
the zoom lens, measured from a vertex of the front lens
group to the back focal plane of the base lens group.

35 The refractive powers of the two groups of the base
lens group are to be selected such that as large an air
space as possible is permitted between the two groups.

– 4 –

The air space should be at least 15% of the installed length of the zoom lens. It is thereby possible that a beam deflector can be introduced into this air space, and thus that an installation space as small and com-
5   pact as possible is created.

With a design principle according to the invention it is possible to design zoom lenses for military recon-naissance which should to have specific optical proper-
10   ties such as, for example, a zoom factor of 8, a vari-able focal range of 34 mm to 272 mm, an aperture number of at least 3.2 and, in a wavelength region from 450 nm to 750 nm, an outstanding optical imaging quality. Moreover, special mechanical properties, such as inte-
15   gration in a compact installation space, must be cre-ated for such zoom lenses. An important role is played, furthermore, by the environmental conditions. Zoom lenses for military reconnaissance must ensure they can function in a wide temperature range from intense cold
20   to excessive heat.

Advantageous embodiments and developments emerge from the further subclaims and the exemplary embodiment de-scribed below in principle with the aid of the drawing,
25   in which:

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1   shows an illustration of the principle of
                a zoom lens for military reconnaissance
                (lens section); and

Figures 2a   show a lens section of a zoom lens of
to 2c   three focal length settings, where
                figure 2a corresponds to f = 34 mm;
                figure 2b corresponds to f = 122 mm and
                figure 2c corresponds to f = 272 mm.

DETAILED DESCRIPTION

Figure 1 shows an illustration of the principle of an inventive zoom lens ZO in lens section for military re-
5   connaissance. The zoom lens ZO comprises a front lens group G1 of positive refractive power, a variator lens group G2 of negative refractive power, a compensator lens group G3 of positive refractive power, a base lens group G4 of positive refractive power and an optical
10 spectral filter 20. The front lens group G1 is constructed from a negative lens 1 and two positive lenses 2 and 3. The negative lens 1 and the positive lens 2 are a split cemented component. This is advantageous because of the large difference in the coefficient of
15 thermal linear expansion α of the two lenses 1 and 2. The positive lenses 2 and 3 are made from FluorCrown (FK) or a comparable material with respect to abnormal partial dispersion.

20 The variator lens group G2 comprises two cemented components, each cemented component having a negative re-fractive power. The positive lenses 4 and 7 of the two cemented components are made from high-index dense flint (SF) glasses of long-crown type. A type of glass
25 is long crown when it holds that $\Delta P_{g,F} > 0$ for the de-viation of the relative partial dispersion $\Delta P_{g,F}$ from the normal straight line. The negative lenses 5 and 6 are of short flint type such as, for example, the dense lanthanum flint (LaSF). Thus, a glass is of short flint
30 type when it holds that $\Delta P_{g,F} < 0$ for $\Delta P_{g,F}$.

The compensator lens group G3 is preferably designed as a cemented component of a positive lens 8 and a nega-tive lens 9.

35

The base lens group G4 is divided into two groups, wherein a first base lens group G4.1 is arranged along

- 6 -

a first optical axis 23 and a second base lens group
G4.2 is arranged along a second optical axis 23'. The
second optical axis 23' is inclined with respect to the
first optical axis 23 at a first angle α different from

5   0° and 180°. In the zoom lens according to the example
$\alpha = 75°$. A relatively large air space for introducing a
beam deflector 18 for beam deflection is provided be-
tween the first base lens group G4.1 and the second
base lens group G4.2. The beam deflector 18 is a plane

10 mirror with a mirror surface having a normal to the
mirror surface 18' wherein the normal to the mirror
surface 18' being inclined to the first optical axis 23
at a second angle which is a half of the first angle α.

15 The distance between the first base lens group G4.1 and
the second base lens group G4.2 should amount to at
least 15% of the overall length of the zoom lens ZO
measured from a vertex of the front lens group G1 to a
back focal plane of the base lens group G4. The beam is

20 deflected by 105° in this exemplary embodiment. The re-
sult is a L-shaped structure of the zoom lens ZO. The
two limbs of the L-shaped installation space thereby
form an acute angle α of 75°. The beam deflection can,
of course, also be performed by a deflecting prism in-

25 stead of the plane mirror 18.

An iris diaphragm 19 is arranged in the direction of
light propagation between the compensator lens group G3
and the first base lens group G4.1. The iris diaphragm

30 19 is imaged by the base lens group G4 such that its
image appears virtually at infinity (∞). Because of pu-
pil aberrations, it is not possible to produce on the
image side a telecentric beam profile for all centroid
rays 22 which are illustrated in figures 2a to 2c. The

35 ray that runs centrally between an upper and a lower
coma ray is designated as centroid ray 22. The iris

- 7 -

diaphragm 19 should be positioned such that a deviation
from telecentricity is as small as possible. The devia-
tion from telecentricity should be at most 1.7°.

5   The position and size of the iris diaphragm 19 are not
changed during the variation in focal length. This
means the distance of the diaphragm to the first base
lens group G4.1 is fixed during zooming.

10   Lens sections are illustrated in figures 2a to 2c for
three focal length settings.
In figure 2a, the focal width is f = 34 mm. The first
base lens group G4.1 of the base lens group G4 has a
positive refractive power and comprises a single lens
15   10 of positive refractive power and a cemented compo-
nent that is assembled from the lens 11 and 12 and is
of positive refractive power. The single lens 10 is
produced from FluorCrown (N-FK51). The positive lens 12
in the cemented component is made from dense phosphate
20   crown (N-PSK53), and the negative lens is made from
lanthanum flint (N-LAF2). The relationships between the
types of glass are in accordance with the Schott glass
catalogue. The lenses 10, 11 and 12 can, of course,
also be produced from other types of glass with compa-
25   rable characteristics. It is important to heed in this
case the abnormal partial dispersion. If glasses from
other manufacturers, for example OHARA, are used, it
must be borne in mind that the refractive index n_d,
dispersion v_d and the abnormal partial dispersion $\Delta P_{g,F}$
30   deviate by at most 10%.

The second base lens group G4.2 of the base lens group
G4 is of positive refractive power overall and prefera-
bly serves as a focusing group. The second base lens
35   group G4.2 can be moved along the second optical axis
23' for focussing in order thus to hold the image posi-
tion, which is displaced in the event of a change in

- 8 -

temperature and air pressure. Since the refractive in-
dexes, the thicknesses and the radii of the individual
lenses are a function of temperature, the image posi-
tion is displaced in the event of a change in tempera-

5   ture and air pressure. At high temperatures, for exam-
ple approximately +60°C, the image position is no
longer situated in a detector plane 21, but behind the
latter. At low temperatures of approximately -20°C, the
image plane is likewise not located in the detector

10 plane 21, but between the optical spectral filter 20
and the detector plane 21. Likewise, objects situated
close by can be sharply focused using the focusing
group G4.2. Consequently, an internal focusing is im-
plemented with the aid of which it is possible to bal-

15 ance out the changes in temperature and air pressure,
and it is likewise possible to focus on objects situ-
ated close by. The variation in focal length and the
internal focusing are independent of one another.

20 The focusing group G4.2 comprises a meniscus-shaped
lens 13, a positive lens 14 that is produced from
FluorCrown (FK), a cemented element composed of the two
lenses 15 and 16, and a negative lens 17. The glass of
the meniscus-shaped lens 13 is of long-crown type. The

25 glass of the negative lens 17 is of short flint type.

The optical spectral filter 20 is an absorption filter
consisting of a colored glass with a vapour-deposited
edge filter. The optical spectral filter 20 is arranged

30 between the second base lens group G4.2 and the back
focal plane of the base lens group G4. The colored
glass is preferably a yellow glass. This longpass fil-
ter glass is distinguished in that it has low transmis-
sion in the short wave spectral region and high trans-

35 mission in the long wave spectral region. Of course, it
is possible here to select with reference to the col-
ored glass used which spectral region is to be passed
and which is to be blocked. The yellow glass corre-

- 9 -

spondingly attenuates the blue and violet light. Conse-
quently, the colored glass restricts the spectral re-
gion beyond ultraviolet (UV). Other colored glasses can
also be used in principle. Slight differences in the
5   refractive index of the colored glasses can be compen-
sated with the aid of the second base lens group G4.2
without loss of imaging quality. The vapour-deposited
edge filter limits the spectral region beyond infrared
(IR). The zoom lens according to the invention is de-
10 signed here for the spectral region from 450 nm to
750 nm. A smaller spectral region can be selected
within this region by selection of colored glass and
edge displacement. It is also possible to displace the
spectral region to 500 nm to 850 nm. The change in the
15 image position can be compensated by using the second
base lens group G4.2.

For specific applications, for example for a periscope
in submarines, it is necessary to produce an image off-
20 set on the detector 21. The image offset is achieved by
tilting or rotating the optical spectral filter 20
around the second optical axis 23'. There should be a
large filter thickness in order to keep the tilting an-
gle as small as possible.

25

The air space between the last lens 17 of the base lens
group G4 and the detector 21 should be optimized with
regard to focusing movement of the second base lens
group G4.2, the thickness and the rotary or tilting
30 movement of the optical spectral filter 20 and of the
installation space of the detector 21, depending on the
special characteristic and focal length of the zoom
lens ZO.

35 The refractive power and the position of the front main
plane of the split base lens group G4 image the iris
diaphragm 19, located at a short distance in front of
the base lens group G4, to infinity or virtually to in-

- 10 -

finity. The position of the iris diaphragm 19 should not be changed during the zooming operation, since the iris diaphragm 19 limits the rays impinging on the base lens group G4. The iris diaphragm 19 should be intro-
5   duced in the zoom lens ZO such that the precondition of telecentricity is retained on the detector 21.

At a specific site, use is made in the individual lens groups of the zoom lens ZO of glasses of long-crown or
10   short flint type. It should be borne in mind with types of glasses that are to be cemented together that the difference in the coefficient α of the thermal linear expansion of the two types of glass is smaller than $2.5 \cdot 10^{-6}/K$, since the zoom lens ZO is used in a rela-
15   tively wide temperature range. If the difference in the thermal coefficients of linear expansion of the two types of glass is greater than $2.5 \cdot 10^{-6}/K$, it is im- possible for the types of glass to be permanently ce- mented.
20

For short focal lengths of the zoom lens ZO, attention centres on the correction of the transverse chromatic aberration, since the image-side principle ray is in- clined to the optical axes 23 and 23' as a function of
25   color in the image of an object point remote from the axis. The transverse chromatic aberration leads to a linear magnification for each color. In the case of long focal lengths of the zoom lens ZO, attention should be centred on the correction of the longitudinal
30   chromatic aberration, since the focal length of the zoom lens ZO is a function of the frequency of the light. Consequently, the focal length for short wave, that is to say blue light is lower than that for long wave, red light. However, a color correction can be
35   fully achieved when types of glass with abnormal par- tial dispersion are used. Such glasses are either of long-crown type or short flint type.

- 11 -

The front lens group G1, the variator lens group G2, the compensator lens group G3 and the first base lens group G4.1 of the base lens group G4 are arranged in
5   the long limb of the L-shaped installation space along the common straight first optical axis 23. The second base lens group G4.2 of the base lens group G4, the optical spectral filter 20 and the detector 21 are integrated in the short limb of the L-shaped installation
10 space. The long limb has a maximum length of 245 mm, the short limb having a maximum length of 115 mm. The lengths of the limbs can be varied depending on the design desired for the zoom lens ZO.

15 The available installation space for the lenses of the groups G1, G2, G3 and G4 are further limited by the position and size of the plane mirror 18 or the deflecting prism, and by the constrictions applying in the air space between the lens 17 and the detector 21. The di-
20 ameter of the front lens group G1 should be at most 90 mm, that of the variator lens group G2, of the compensator lens group G3 and of the base lens group G4 should be limited to at most 45 mm.

25 In figure 2b, the focal length of the zoom lens ZO is $f = 122$ mm. In order to be able to realize this focal length, the variator lens group G2 and the compensator lens group G3 are displaced in the direction of the first base lens group G4.1 of the base lens group G4
30 along the first optical axis 23. The distance between the variator lens group G2 and the compensator lens group G3 has become minimally smaller by comparison with figure 2a.

35 The focal length of the zoom lens ZO is $f = 272$ mm in figure 2c. The aperture number is 3.2 here. In order to achieve a focal length of $f = 272$ mm, the variator lens group G2 is displaced right up to the compensator lens

- 12 -

group G3 along the first optical axis 23. As in fig-
ures 2a and 2b, here, as well, a cone 22' and a cen-
troid ray 22 of a further cone (not illustrated) are
imaged in order to display the optical path.

5

The first angle α between the long limb and the short
limb of the L-shaped installation space is 75° in all
three figures. The first angle α can also be of vari-
able design, wherein the first angle α should be pref-
10   erably in the range between 50° and 130°. For example,
the first angle α can have a value of 85°, although it
should be borne in mind that the focusing characteris-
tics can still be realized. If there is no precondition
limiting the installation space, it is also possible
15   that there need be no beam deflection. Consequently,
there is also no need for a plane mirror 18 for beam
deflection.

A CCD detector whose image diagonals are 21.45 mm is
20   used as receiver 21.

It is possible with the aid of this design to implement
a zoom lens ZO that satisfies the requirements with
reference to the zoom factor, the focal range, the ap-
25   erture number, the image diameter, the telecentric po-
sition of the exit pupil and the focusing characteris-
tics, for example, for military reconnaissance. More-
over, a very good polychromatic correction of the zoom
lens ZO can be achieved with the aid of this design.

30